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WILDFIRE RISK ALONG THE WILDLAND-URBAN INTERFACE IN OKLAHOMA IN RELATION TO ENCROACHING EASTERN REDCEDAR

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WILDFIRE RISK ALONG THE WILDLAND-URBAN INTERFACE IN OKLAHOMA IN RELATION TO ENCROACHING EASTERN REDCEDAR

A THESIS APPROVED FOR THE DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL SUSTAINABILITY

BY THE COMMITTEE CONSISTING OF

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ABSTRACT

Across the United States, the number of wildfires has been increasing, but this can especially be felt in the Great Plains, where some of the most drastic increases in wildfire frequency and size have occurred (Donovan et al., 2020). While frequent fires should seem somewhat normal in a grassland biome like Oklahoma, after European settlement, fire suppression has allowed woody vegetation, like Eastern Redcedar, to encroach onto the grasslands and dominate native vegetation (Donovan et al, 2017; Donovan et al, 2020; Twidwell et al. 2021). This leads to state transitions of a grassland biome to a woodier ecosystem, which can cause more intense wildfires. The metropolitan areas outside of Oklahoma City and Tulsa have the highest housing and population densities at risk and largest magnitude of wildland-urban interface. But some rural areas like Hinton and Woodward to Watonga show a high risk to wildfire in proportion to their low populations. Landowners need to properly manage these areas to prevent fires rather than suppressing them.

CHAPTER I: INTRODUCTION

Across the United States, the number of wildfires has been increasing, but this can especially be felt in the Great Plains, where some of the most drastic increases in wildfire frequency and size have occurred (Donovan et al., 2020). While frequent fires should seem somewhat normal in a grassland biome like Oklahoma, after European settlement, fire suppression has allowed woody vegetation, like Eastern Redcedar, to encroach onto the grasslands and take over (Donovan et al, 2017; Donovan et al, 2020; Twidwell et al. 2021). This leads to state transitions of a grassland biome to a woodier ecosystem, which can lead to more intense wildfires. Those living along the wildland-urban interface and their property are at a higher risk of being affected by wildfire.

This paper aims to understand the magnitude of the wildland-urban interface in Oklahoma and identify locations where wildfire is a higher threat to people and property. This will be determined by asking:

- What is the magnitude of wildland-urban interface in Oklahoma?
- Which climate divisions have the highest populations and property at risk?
- What locations are at highest risk of wildfire from Redcedar?

1 .1 Grassland biomes and Fire

The state of Oklahoma is mostly in the Great Plains region. These ecoregions were established by the Environmental Protection Agency at various levels of detail (US Environmental Protection Agency, 2013). Oklahoma is covered in many different types

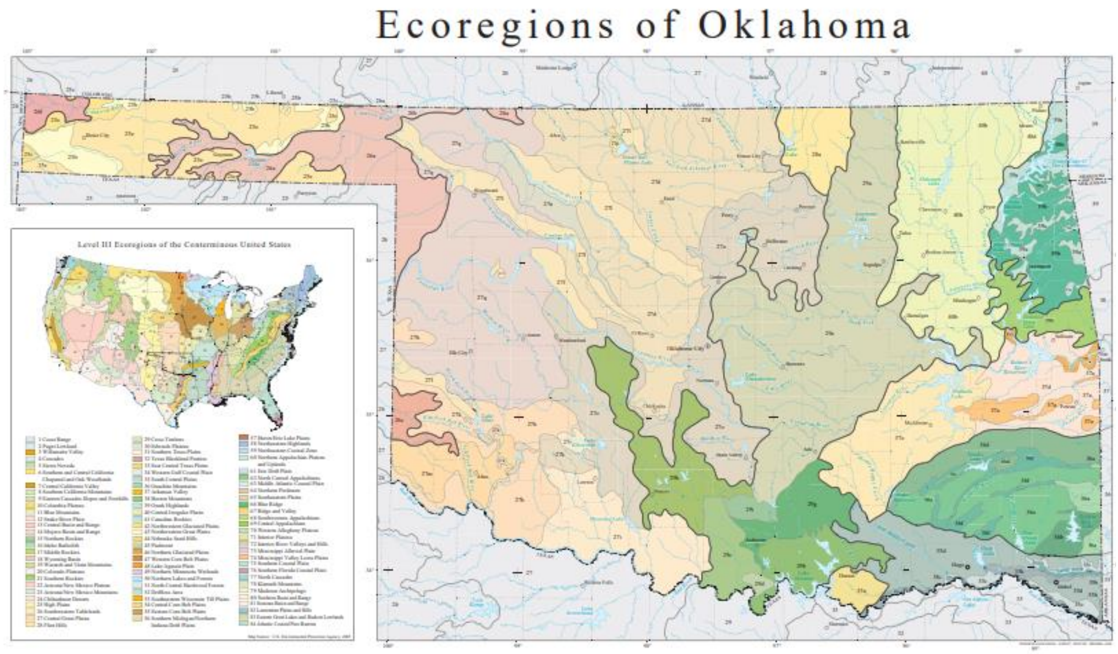


Figure 1. Ecoregions of Oklahoma, Source: US EPA

of vegetation, ranging from grasslands to shrublands to forests (Figure 1). The one category that covers the most area in Oklahoma is tallgrass prairie (Tyrl et al., 2017).

Historically, these regions would see a higher frequency of wildfire compared to other types of land cover (Donovan et al., 2020). Grasslands are resilient to fire; they readily burn and easily return to pre-fire vegetation levels (Zouhar, 2021). They rely on fire to maintain their ecosystem by reducing leaf litter and woody encroachment. According to Ratacjzak et al. (2014), grasslands in the Central Great Plains should have a fire interval of one to three years.

Although much of Oklahoma is cropland and prairie, there are also shrublands and forested regions of the state. These regions contain mostly oak and hickory trees, with some pines showing up in the southeast. The transition zones between these regions of woody vegetation and prairies are called the Crosstimbers. Much of the central region

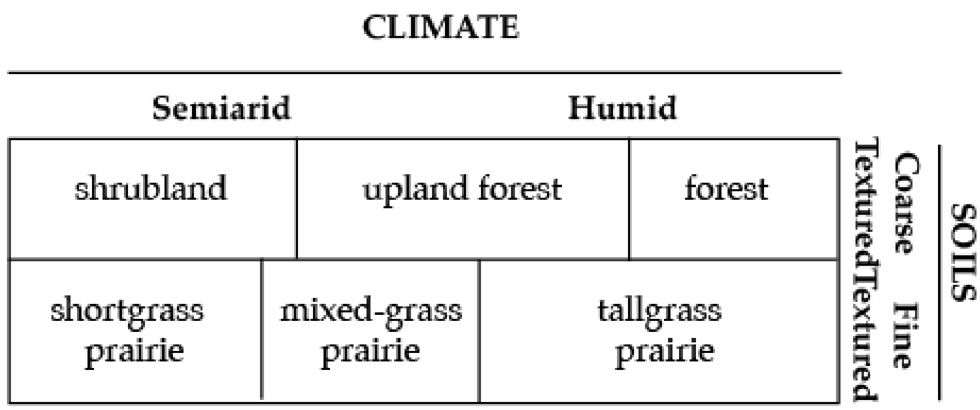


Figure 2. How native vegetation grows in Oklahoma, Source: Tyrl et al., 2017.

of Oklahoma is within the Crosstimbers. The relationship between climate and soil type is a good indicator of what vegetation types should be expected in what locations, shown in Figure 2. Exceptions to this chart can be made for certain woody vegetation types, like Eastern Redcedar, that encroach onto lands and take over the native vegetation type (Tyrl et al., 2017). An expected fire interval for a shrubland would be from three to eight years, shifting to a woody ecosystem when the fire interval is greater than ten years (Ratacjzak et al., 2014).

This map from Guyette et al. (2012), shows the historic fire interval of Oklahoma compared to the rest of the United States (Figure 3). Over a 200-year period from 1650 to 1850, the majority of Oklahoma fell within the four to six year five intervals, with the panhandle having a longer return period. The South Central region along the Red River shows the shortest fire interval of two to four years. During drought or periods of dormancy, vegetation would ignite from sources like lightning. Native Americans also maintained the grassland with burning, seen through a decline in their population correlating with a decline in fire frequency (Tyrl et al., 2017).

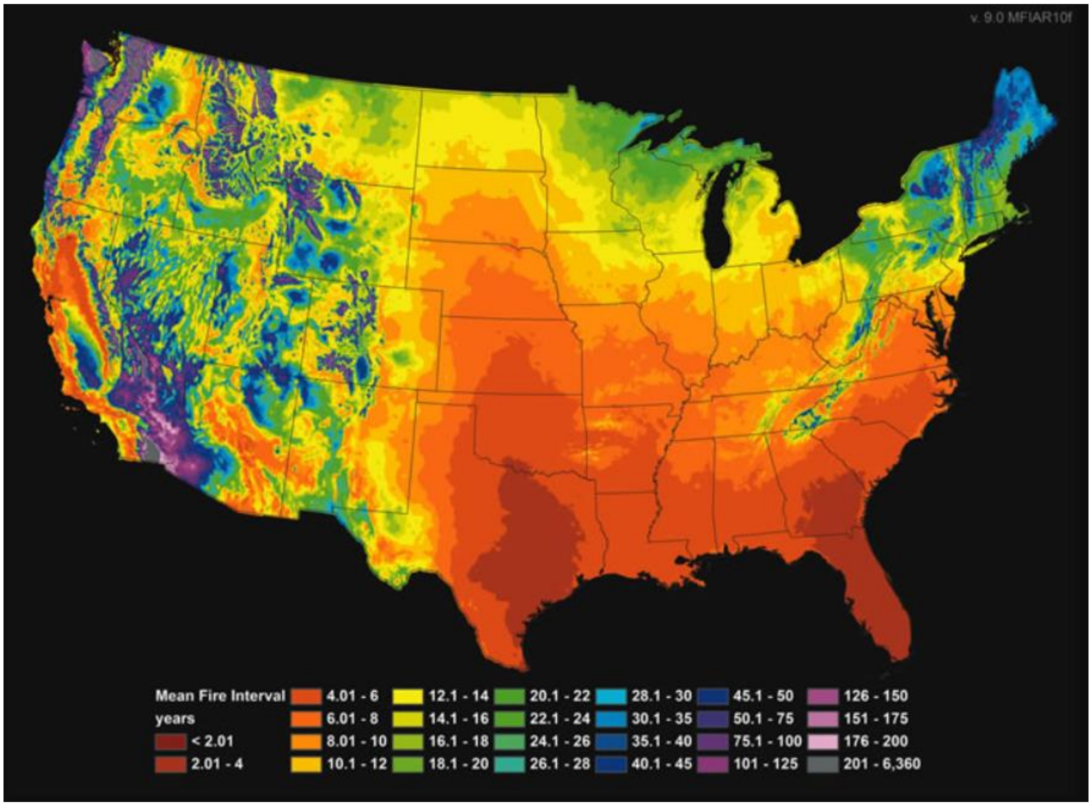


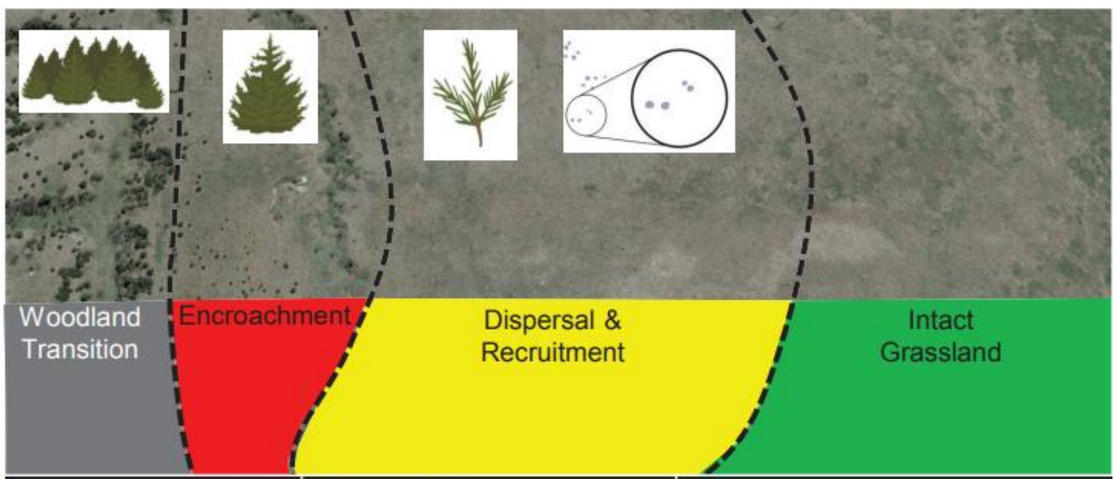
Figure 3. Historic fire regimes 1650-1850, Source: Guyette et al., 2012.

After European settlement, fire intervals started increasing. The new settlers that came in drastically changed the way the land was managed. Fences changed grazing patterns which in turn affected the way fire could return. According to Rooney and Stambaugh (2019), fire intervals across the state ranged from one to 66 years, but the average was around 6.8 years. Although not as drastic as 66 years, this average is still higher than the historic average. Between the conversion to agriculture fields, development, and fire suppression techniques, wildfire was becoming rare in the Great Plains. (Donovan et al., 2017; Tyrl et al., 2017). The land started transitioning into the Crosstimbers, where woody vegetation started to grow and take over lands that were historically prairies.

1.2 Encroachment

Encroachment of woody vegetation is threatening the landscapes at a rate where restoration is not possible (Twidwell et al., 2021). It starts with the seeds dispersing into grasslands through natural means like wind or animals. Historically, frequent fires would burn the seeds or seedlings that were growing in the grasslands and return the biome to its native state. Without fire, seedlings quickly establish themselves in these regions along the edges of forests and grasslands and start competing with the native plants.

When these seedlings grow large enough to disperse their own seeds, the encroachment stage has been reached (Figure 4). This is when there starts to be a higher



Stages	Description	Management
Woodland Transition	Woody plant dominance	Heavy machinery - mechanical removal, fire
Encroachment	Scattered producing trees	Hand tools, heavy machinery - mechanical removal, fire
Dispersal & Recruitment	Intact with seedlings or incoming seed	Fire, hand cutting, haying, mechanical removal, browsers
Intact Grassland	Treeless with no seed	Avoid introducing seed

Figure 4. Eastern Redcedar Stages of Encroachment, Source: Twidwell et al., 2021.

percentage of woody vegetation than native grasses. Eventually, one will take over the other. Without intervention, the trees will take over the grass, as they cannot coexist (Twidwell et al., 2021). It is often difficult to determine areas of encroachment without going into the field. Trees cover much of the understory where seedlings are starting to grow, so it is not possible to remotely sense that data.

1.3 Eastern Redcedar

While woody encroachment is a problem in the Great Plains, Eastern Redcedar poses its own problems to the landscape. Once Redcedar seeds are dispersed onto a neighboring grassland, most likely by a bird, they germinate within two years. They quickly reach maturity, which keeps them from easily dying in a wildfire and starts the process of dispersal over again. Over 1.5 million seeds can come from one mature Redcedar in a year. One study shows that the dispersal zone of Redcedar is within 100 yards of the source (Twidwell et al., 2021).

Eastern Redcedar are considered a hazardous fuel for the way that they burn. This specific type contains volatile oils that make the tree ignite and burn more easily than other prevalent woody vegetation in the state like oak or hickory. Once it starts burning, it is easy to catch other vegetation and objects around it on fire; however, Redcedar often do not get hot enough to die in the fire, which does not aid the grasslands with historic biome restoration (Elmore, 2017).

1.4 The Wildland-Urban Interface

The problem with woody encroachment is that it puts more people at risk of wildfire in two ways: woody vegetation can germinate in areas that are already developed, or development can branch out into rural areas near groves of trees (Radeloff et al., 2018). Redcedar was commonly used as a fence along ranches in rural Oklahoma, which puts humans and properties near vegetation that can easily ignite and spread fires. The "zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels" is formally known as the wildland-urban interface (WUI) (*What is the WUI?*, 2021). With recent fire suppression tactics, the WUI has been increasing, putting more people at risk of a large magnitude wildfire. In the United States, the WUI increases by about two million acres a year (*What is the WUI?*, 2021).

One thing that makes the wildland-urban interface so dangerous is the human component. This is where most fires ignite. Eighty-four percent of wildfires are human caused, and the majority start on private lands even though most people want to put public forests at fault (PBS Terra, 2022; Radeloff et al., 2018). Not only are there more wildfires, but they "pose a greater risk to lives and homes, they will be hard to fight, and letting natural fires burn becomes impossible" (Radeloff et al., 2018). WUI generally lies outside of a municipality, which would have more direct access to resources. Unfortunately, due to the nature of the rural roads and remote home locations, firefighters are not able to quickly reach and fight these fires (Figure 5).

In Oklahoma, many people are choosing to live on the fringes of cities. Urban growth is not increasing in density but in sprawl as these outer edges of established areas grow instead of their city centers (Drake and Todd, 2002**)**. Often these areas do not have established building code or fire restrictions, adding to the threat of destruction of life and property. Structures in the lower housing density areas are more likely to burn because of this lack of regulations; however, when high density housing that is surrounded by grassland and vegetation sparks, the houses become fuel for each other (PBS Terra, 2022).

1.5 Prescribed burns

A way to reduce the threat of Eastern Redcedar and wildfire to property along the WUI is to conduct a prescribed burn. This helps control the encroachment of woody species in the same way that it would naturally occur. It is the most effective way to manage woody species; mechanical measures can be extremely costly (Bidwell et al., 2021). In order to be effective, the land would need to be burned within the first six years of Redcedar growth, before the tree becomes big enough to be resistant to fire.

Because most of the WUI is on private lands, it is up to the landowner to decide what to do with the property. Some landowners have formed Prescribed Burn Associations (PBA) to help each other conduct these prescribed fires. They host workshops, share equipment, and even have opportunities for grants. (Bidwell et al., 2021; Twidwell et al., 2021). What keeps most landowners from conducting a prescribed fire on their property is the liability concerns. Some are worried about what would happen if the fire escaped, but Weir et al. (2020) explains how rare it is that a fire would escape, or an insurance claim would come from a prescribed burn.

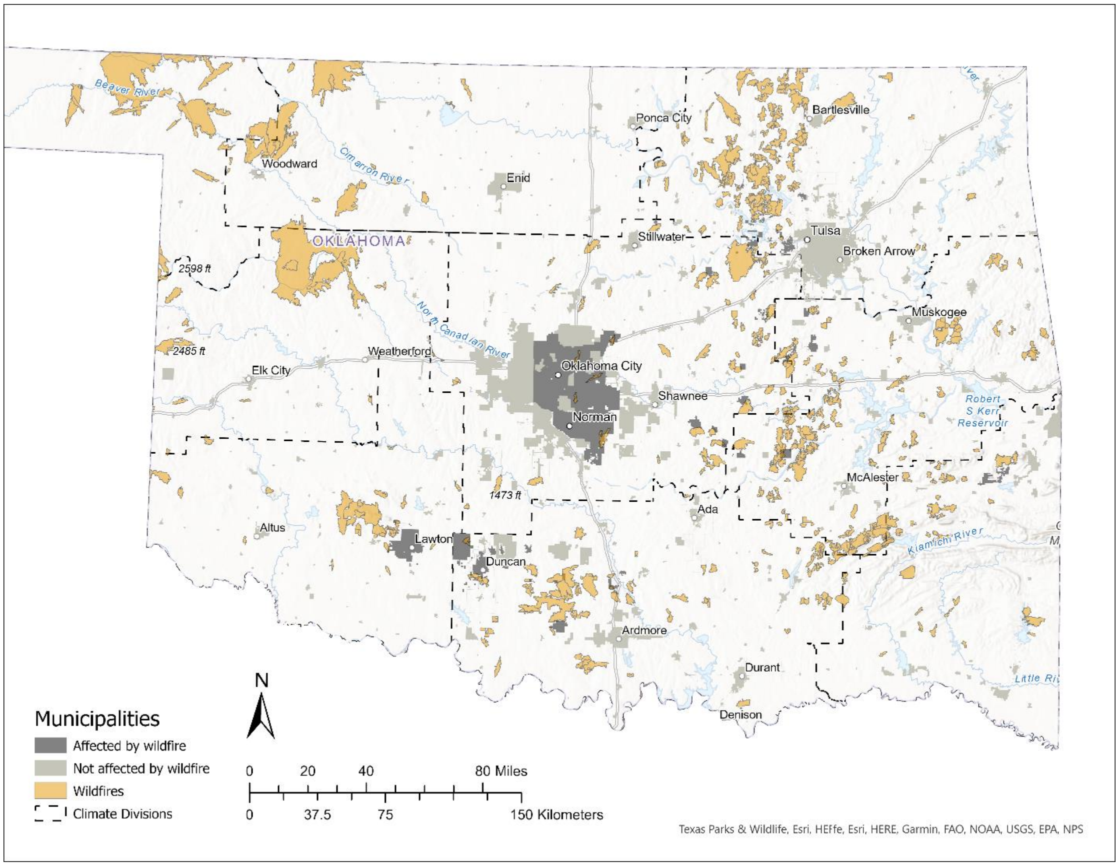


Figure 5. Wildfires from 2000-2020 and municipalities in Oklahoma that were and were not affected by those wildfires

Another factor contributing to fire suppression is absentee landowners. People who are not living on their land cannot understand the magnitude of woody encroachment on their property. They are also less likely to be proactive about controlling because they are not around to supervise a controlled burn. Between absentee landowners and liability issues, land management is not a top priority for enough people on private lands, which makes the management of Redcedar almost impossible (Weir et al., 2020).

1.6 Literature Review

Studies have been done showing the fire intensity and location shift across the country in recent years. In these cases, the study region has been the entire Great Plains which reaches northward from Oklahoma into Kansas and Nebraska (US Environmental Protection Agency, 2013). Donovan et al. (2020) has shown the link between the shift from grasslands to woody ecosystems and wildfire occurrence by identifying patterns in USGS ecoregions. Using land use and percentages of burned area, they were able to determine what ecoregions disproportionately burn. They found that the Crosstimbers saw a 3900% increase in frequency of large wildfires between 1985 and 2014.

Donovan et al (2020) found that this increase was most likely to occur in grasslands and woody vegetation. Grasslands are expected to have a high frequency of wildfires since that is how they naturally maintain themselves (Zouhar, 2021).. This land cover category was found to have the most area burned, but it also covers a large part of the Great Plains. Consequently, annual area burned as a percentage of total area is fairly low. The area of woody vegetation burned was disproportionately more than the area it comprises within the Great Plains region. This means that Oklahoma is shifting to a riskier ecosystem with encroaching Redcedar and the Crosstimbers playing a part in wildfire frequency.

Similar to Donovan et al (2020), a study by Radeloff et al (2018) aims to understand the wildfire risk, but this specifically looks at the expanding wildland-urban interface. Using housing density at the block level compared to NLCD raster imagery, they map the WUI in the United States. They found that although wildfires are a risk along the WUI, it is not stopping people from moving out there. Adding housing fuels the problem, but other factors, like climate change, play a part in increasing wildfire frequency also (Radeloff et al., 2018).

Having a disproportionately high frequency of wildfires in the grassland and woody regions increases the threat to people and property along the wildland-urban interface (Donovan et al., 2020). Not only do they add to the frequency, but the volatile nature of Redcedar increases the intensity of these events. Firefighters must take a lot into consideration when fighting these types of fires to stay safe while also being efficient. The increased intensity not only adds to the difficulty of suppressing the fire but poses a higher threat to their lives. The cost to fight these fires is expensive due to their remote locations and need for more resources.

A study by Hoff et al (2018) shows an increase of approximately 38% to the Eastern Redcedar fuel load within the Crosstimbers of north central Oklahoma. The expanding WUI only adds to the negative impact on biodiversity that is seen with encroaching woody vegetation (Radeloff et al., 2005). The Great Plains have been studied to understand the changing environment, but this is not specific to Oklahoma. Since every ecoregion in the Great Plains has either seen increases in wildfire frequency, area burned, and wildfire probability, it makes sense to break this down on a smaller level.

My study is specific to Oklahoma and aims to answer the following questions:

- What is the magnitude of WUI in Oklahoma?
- Which climate divisions have the highest population at risk?
- What locations are at highest risk of wildfire from Redcedar?

I will look at urban and rural areas within climate divisions to understand where wildfire risk lies. I expect to find a large magnitude of WUI along expanding metropolitan areas, and, therefore, a higher wildfire risk in those areas.

Chapter two will discuss my data and data sources, as well as methods of analysis used. The next chapter is the presentation of my results. This includes most of my tables and figures. Chapter four then covers my discussion of my results. This is the concluding chapter of my thesis.

CHAPTER II: DATA AND METHODS

2.1 Study Area

Wildfires are fuel-driven or wind-driven events (PBS Terra, 2022). In Oklahoma, most wildfires occur during periods of dormancy or low precipitation, leaving a lot of dry vegetation and fine fuel. The state has many windy days that can see high gusts over a long span of time. The size of the fire depends on these three factors: relative humidity, rainfall, and wind speed (Weir et al., n.d.). It is vital to understand the fuel availability of an area when weather conditions are within the right margins. (Donovan et al., 2020). The changing climate is also a contributing factor to increasing wildfire frequency and does not bring relief (Scasta et al., 2016).

Because of this relationship between wildfires, weather, and climate, I chose to look at the state by the climate divisions. The climate divisions were developed by the National Oceanic and Atmospheric Administration for the entire United States. There are 344 climate divisions total, with nine being in Oklahoma. These divisions have changed and developed throughout the years. In the beginning, land was divided by averaging the temperature and precipitation and grouping similar results. Because the climate divisions were being used as reference for more than just farmers but also in power development and water resources, topography was added as a factor along with the temperature and precipitation in 1909. At one point, the Climatological Service created only twelve divisions for the entire nation, but this format was done away with due to difficulties in communication over such a large area. In 1949, it was decided to use the same boundaries as the crop reporting districts due to the relationship between crop type and climate classification. (Guttman and Quayle, 1996). Because of this relationship, I applied the same principles to Redcedar, hypothesizing that risk of wildfire from Redcedar would correlate by climate division due to fuel availability and live fuel moisture.

Satellite imagery of Oklahoma shows the variation in vegetation from east to west in the state (Figure 6). This is displayed in the imagery with lush greenery on the east side of the state where most precipitation falls, and dry land in the west, where they do not receive as much rain. The Oklahoma Mesonet shows that over a period of 30 years, the highest average rainfall is found at Mt. Herman in McCurtain County with 57.7 inches a year (Figure 7). This falls in climate division nine, the Southeast. The lowest average rainfall is found in the Panhandle at 15.7 inches. Because this average is so low, the

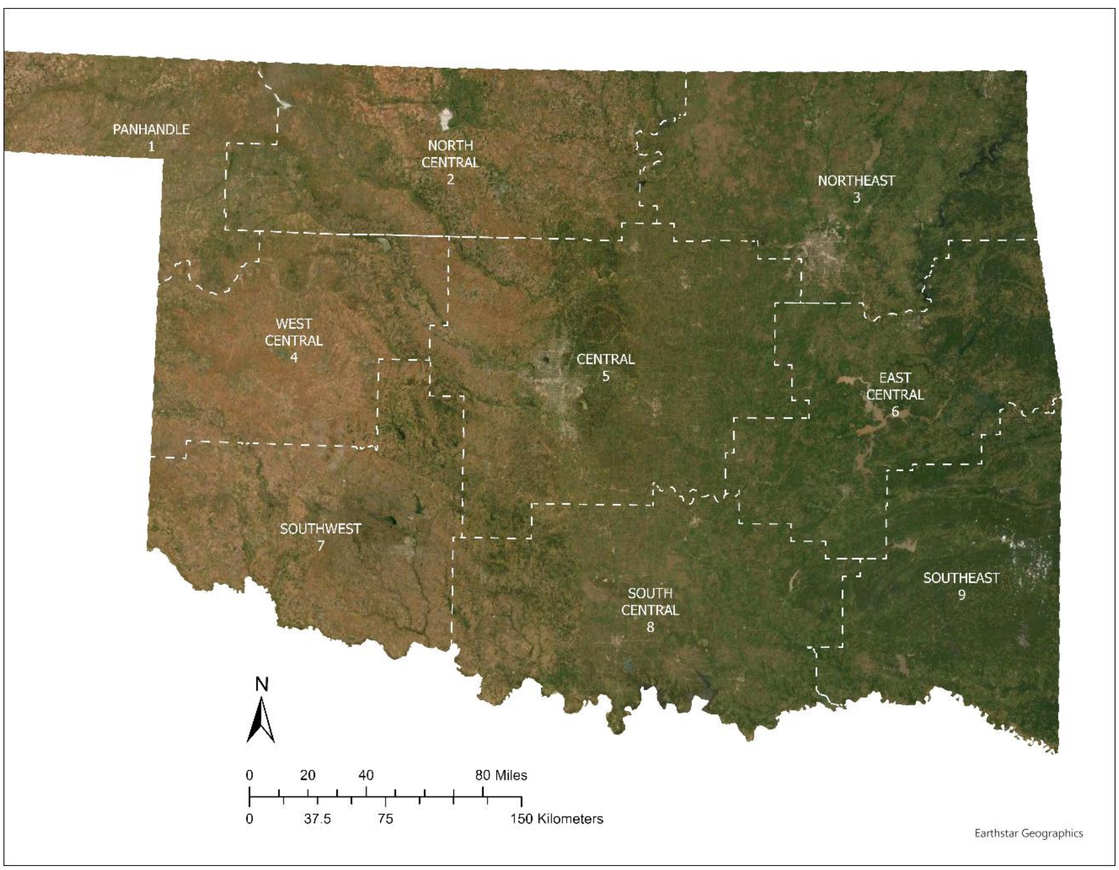


Figure 6. Climate divisions of Oklahoma, Source: NOAA

environment does even promote the growth of Eastern Redcedar, but they are expected to be found in the wetter, forested regions of Oklahoma.

The state also sees average temperatures increasing from north to south. The Oklahoma Mesonet shows normal annual temperatures ranging from 56 degrees Fahrenheit to 65 degrees Fahrenheit, with the warmest region of the state being along the Red River on the southern Oklahoma-Texas border (Figure 8). The high can be found in the South Central climate division eight and the low is again found in the panhandle. According to Scasta et al. (2016), “fire frequency generally increases from west to east due to precipitation and north to south due to temperature,” just like Oklahoma’s precipitation and temperature averages.

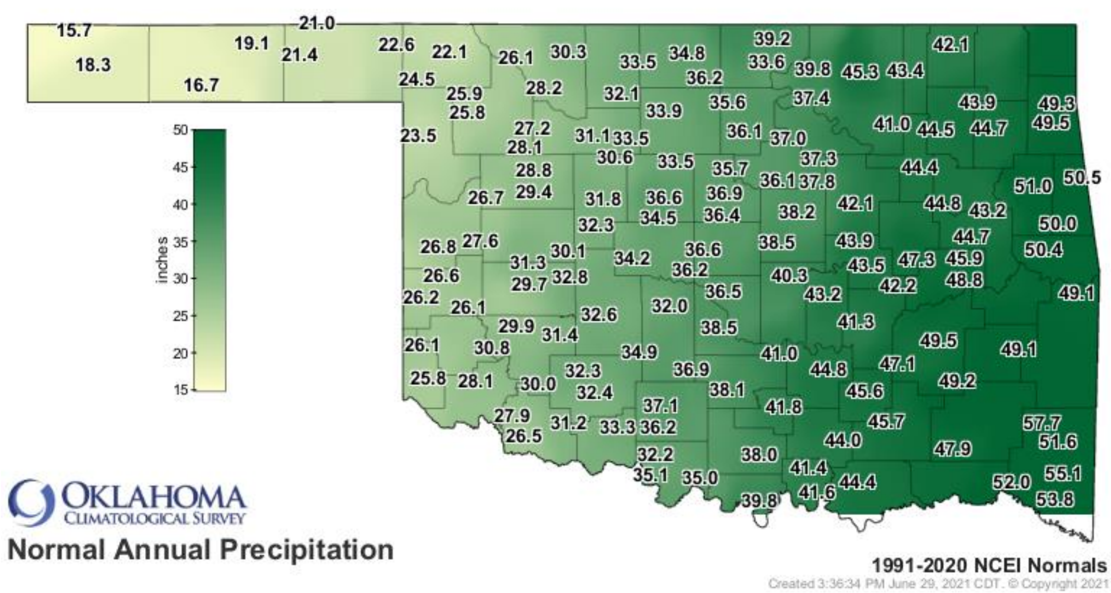


Figure 7. Average precipitation in Oklahoma from 1991-2020, Source: Oklahoma Climatological Survey

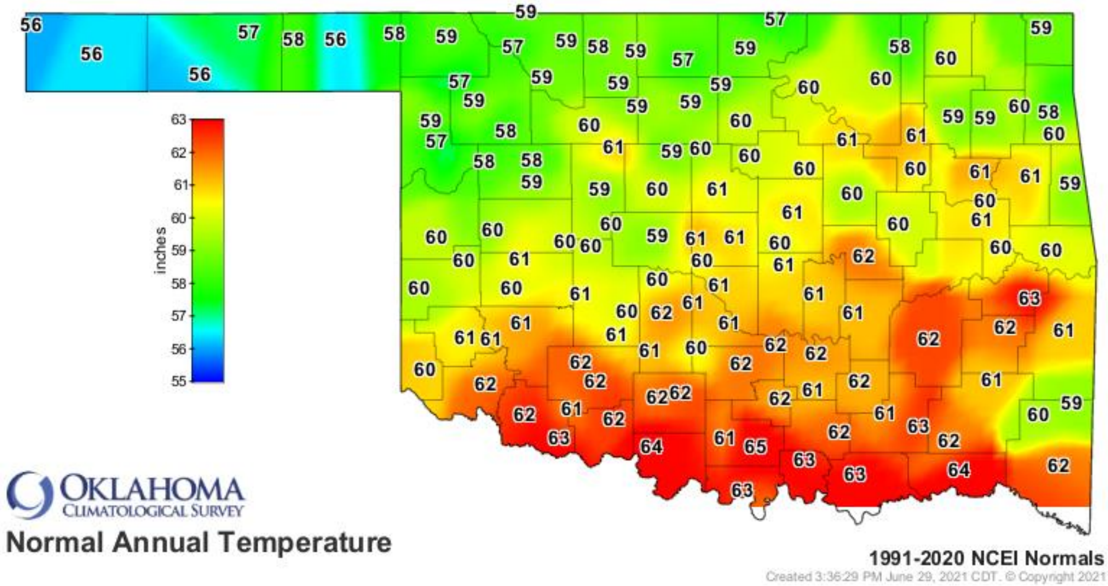


Figure 8. Average temperature in Oklahoma from 1991-2020, Source: Oklahoma Climatological Survey

<u>2.2 Data</u>

Data for this project comes from multiple existing open sources on the internet. Population data comes from the American Community Survey (ACS) tables by the US Census Bureau from the most recent census in 2020. This data is at block level to be as specific as possible when identifying areas of greater population density. A smaller areal unit means that densities can be calculated at the highest resolution. Housing density is also from the ACS tables five-year estimates. Census block groups and state boundaries come from the Census Bureau's TIGER/Line shapefiles. Population density is not a pre-calculated field from the Census Bureau, so I recalculated the block group area into units of square miles. I then created a new field and calculated the density using the total population field (p1_001n) and the area in square miles.

Other boundaries include the climate divisions that come from the National Oceanic and Atmospheric Administration (NOAA). This layer includes all 344 divisions across the United States, so I extracted the regions that were in Oklahoma and exported them as their own feature. Municipalities were downloaded from the Center for Spatial Analysis data warehouse. The wildfire polygon data is a part of the Monitoring Trends in Burn Severity project that is a coordinated effort between the USGS Center for Earth Resources Observation and Science (EROS) and the USDA Forest Service Geospatial Technology and Applications Center (GTAC). This dataset includes fire perimeters from 1984 to current. With the latest quarterly update, the number of features available for view and download total 29,533. The MTBS dataset contains all fires greater than 1,000 acres in the West and 500 acres in the East, so small fires are not included. I downloaded recent wildfires from 2000-2020 in the state of Oklahoma. Each year was a separate layer, so I appended them all into one. This gave me one layer with 607 records.

For land cover data, I considered using the National Land Cover Dataset (NLCD) by the Multi-Resolutions Land Characteristics (MRLC) Consortium. This is a raster layer at 30m resolution with twenty different land cover classifications. There is a higher resolution dataset derived from the NLCD at 10m developed by the Oklahoma Biological Survey and Missouri Resource Assessment Partnership. The Oklahoma Ecological Systems map features 165 vegetation types, giving a much more detailed look at the land cover of the state. The dataset was published in 2015. Since this project aims to understand the proximity of Redcedar and urban areas, all vegetation categories containing those words were extracted from the layer to simplify the analysis.

One disadvantage to this dataset is that it does not show change in land cover over time because there is only recent data available. Getting such a high-resolution raster layer takes a lot of time between remote sensing and field research. Even the NLCD is only available for every few years. But the NLCD does not provide the detail when it comes to determining tree cover of forests. Because of the nature of encroaching Redcedar, it does not fit neatly into the deciduous, evergreen, and mixed categories provided by the NLCD. While the Oklahoma Ecological Systems map is limited to one point in time, the amount of detail and precision put into the layer makes up for the inability to accurately compare attributes on a temporal scale.

2.3 Analysis Methods

Some of the wildfire perimeters stretched into neighboring states like Kansas and Texas, so the overall wildfire layer was clipped to only the state of Oklahoma since that is the study area. The data was symbolized by their unique values with the field as their ignition date, grouped together by each year (see Figure 9, next chapter). For the wildfire hot spot map (see Figure 10, next chapter), a Getis-Ord Gi* analysis was run on these wildfire perimeters using the area as the analysis field. This analysis finds hot spots and cold spots of significant events. A hot spot would show a geographic cluster of large magnitude events at varying confidence intervals.

To answer my research question about determining the magnitude of wildland-urban interface in Oklahoma, the WUI first had to be calculated. This was done by identifying the areas of Redcedar and urban land cover that intersect each other (Radeloff et al., 2018). Once these vegetation types were selected out of the Oklahoma Ecological Systems map layer, I created a layer separately for the forested regions and urban areas.

This left me with 22 different vegetation types specific to Redcedar with almost 1,000,000 records in the layer. The urban categories only delineate between low and high intensity, and this layer had just over 158,000 records. I then ran an Intersect with the two polygon layers and chose an output type of line. Because this is land cover, these categories do not overlap, so creating a polygon layer would not be possible.

I ran a spatial join in the new wildland-urban interface polyline layer with the climate divisions polygon layer from NOAA with the WUI as the target feature and climate divisions as the join feature. For the operation, I chose one-to-many at the Intersect. This provided a table categorizing the WUI by the climate division in which they were located. From there I was able to summarize the statistics on various fields calculating their means, sums, and standard deviations with the case field being climate divisions. Then I exported it into Table 2 (next chapter). This same analysis was done with the wildfires layer as the target feature. Table 1 was created from summarizing the area of the wildfires by climate division.

Another research question was to determine the population at risk of wildfire by living along or near the wildland-urban interface per climate division. This was analyzed through two separate methods. The first was using the WUI layer calculated previously by taking the intersection of urban and Redcedar land cover. The geoprocessing tool Buffer was used to add varying perimeters to the WUI, one at a quarter mile and one at a half mile, with the buffers being dissolved while processing. These buffer distances were chosen to show the range in which an ember might start a spot fire.

According to Page et al. (2019), the majority of spot fires are expected to be less than 500m (0.31 mile). Under fair weather conditions in Oklahoma, spot fires are not likely to ignite much farther, according to John Weir, an expert in Oklahoma fire weather and behavior (J. Weir, personal communication, September 30, 2022). With a more active weather pattern, spotting distance potential can increase, especially with a species like Redcedar that produces many embers. For minimum spotting distance, a quarter mile buffer was created, and for maximum distance, a half mile buffer was created. (Weir, 2022; Engle and Stritzke, 1992; Page et al., 2019). Even in windy conditions across western Oklahoma, spot fires rarely exceed a half mile.

From there, I selected block groups by location at the intersection of the two separate buffer zones. For the quarter mile buffer this gave me 3100 block groups within the buffer region and for the half mile buffer there were over double at 7000 block groups. These selections were then exported out as their own layer. Those layers were spatially joined to the climate divisions so that the statistics of the total population and density could be summarized per division.

The second method I used to determine population and property at risk was the housing density of each climate division (Radeloff et al., 2018). I used the same WUI buffers as I used on population density on the housing units block group layer. I selected the block groups by location that intersected a buffer zone. I exported the selection into a new layer and added area and density fields. A new “housing” field had to be added in order to calculate housing density because the original field was a text type, which cannot be used in the field calculator. The area was calculated by geometry of the block group in square miles, and then the density was the new long type housing units divided by the area.

This layer was then symbolized by the density by graduated colors on five natural breaks. From there, the same process as the population density layer was followed. I spatially joined the housing density layer to the climate divisions with the block groups as the target feature and climate divisions as the join feature. A Match option of 'have center within' was used to join them one-to-many. Then, the attributes could be summarized by the climate divisions to present a table (Tables 4 and 5, next chapter) with density means and housing sums per division.

The projection used for analysis was the USA contiguous Albers equal area conic projection. This is centered over the United States and particularly well over Oklahoma to preserve area. This projection was used over a Mercator since the study area is oriented east-west rather than north-south.

CHAPTER III: RESULTS

Oklahoma saw an average of 30.35 wildfires per year from 2000 to 2020. But from year to year, frequency, location, and magnitude can vary greatly. Climate change continues to contribute to the unpredictability of weather patterns, which leads to the unpredictability of wildfires. Figure 9 shows wildfires occurring in the state of Oklahoma from the year 2000 to 2020 per climate division. From looking at the map, not one year stands out regarding the number of fires in any particular year. There is a variation spread out among the years, so one color does not pop over the others.

What does stand out is the magnitude of some of these wildfires. There are a few

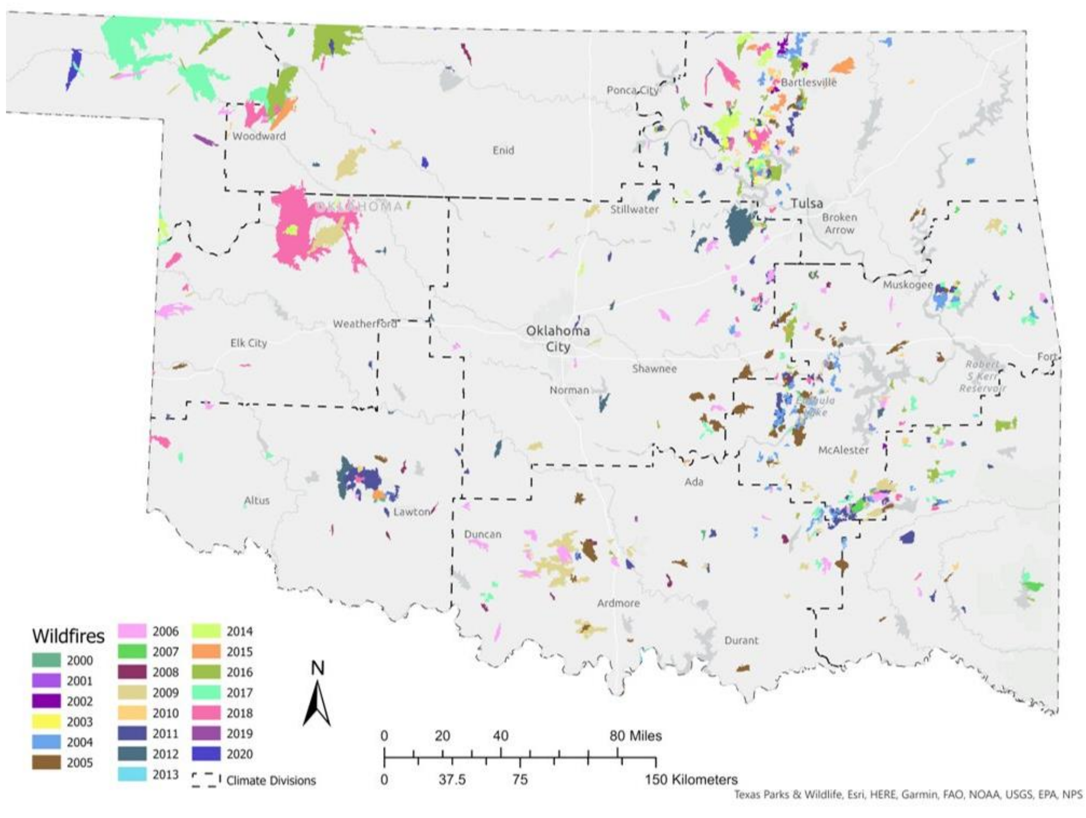


Figure 9. Wildfires by year, 2000-2020

large ones along the Oklahoma-Kansas border including the Anderson Creek Fire in 2016 and the Starbuck fire the following year. These fires burned in the North Central division, climate division two, and the Panhandle, climate division one, respectively. The Anderson Creek Fire burned nearly 140 square miles of land while the Starbuck fire was over 300 square miles. The Freedom Hill fire in 2012 stands out as a more notable fire that happened closer to population centers of Oklahoma. This burned 89 square miles of land in the Central climate division. However, the wildfire that stands out the most and is probably one of the more memorable events in Oklahoma wildfire history is the Rhea fire of 2018 south of Woodward. The West Central climate division four lost 434 square miles over the course of that fire.

Most of the other fires are seemingly small and scattered throughout the state. Some climate divisions saw a high amount of area burned because of frequency of fire, while others were due to the magnitude of the fire (Table 1). Examples of this would be

Wildfires per climate division			
Climate division	Frequency	Total area (sq mi)	Average area (sq mi)
1	26	829.8	31.9
2	22	967.2	44.0
3	144	858.7	6.0
4	19	617.7	32.5
5	83	471.6	5.7
6	196	906.4	4.6
7	30	216.0	7.2
8	80	498.7	6.2
9	60	285.4	4.8

Table 1. Wildfires per climate division in square miles

climate division six (East Central) and climate division two (North Central). Climate division six saw 196 fires over the course of twenty years, but the area burned was only an average of 4.6 square miles per incident. Climate division six had the largest frequency of fires out of all nine divisions and second greatest total area burned, but the average size of the fire was the smallest out of any division. On the other hand, climate division two only had twenty-two fires over the same twenty-year span, but the mean area burned was forty-four square miles. Division two had the greatest area burned over the years. The second highest mean area burned (climate division four) saw a similar number of fires at nineteen, but the area averaged 32.5 square miles per event.

This hot spot analysis of the wildfires in Figure 10 shows where there is

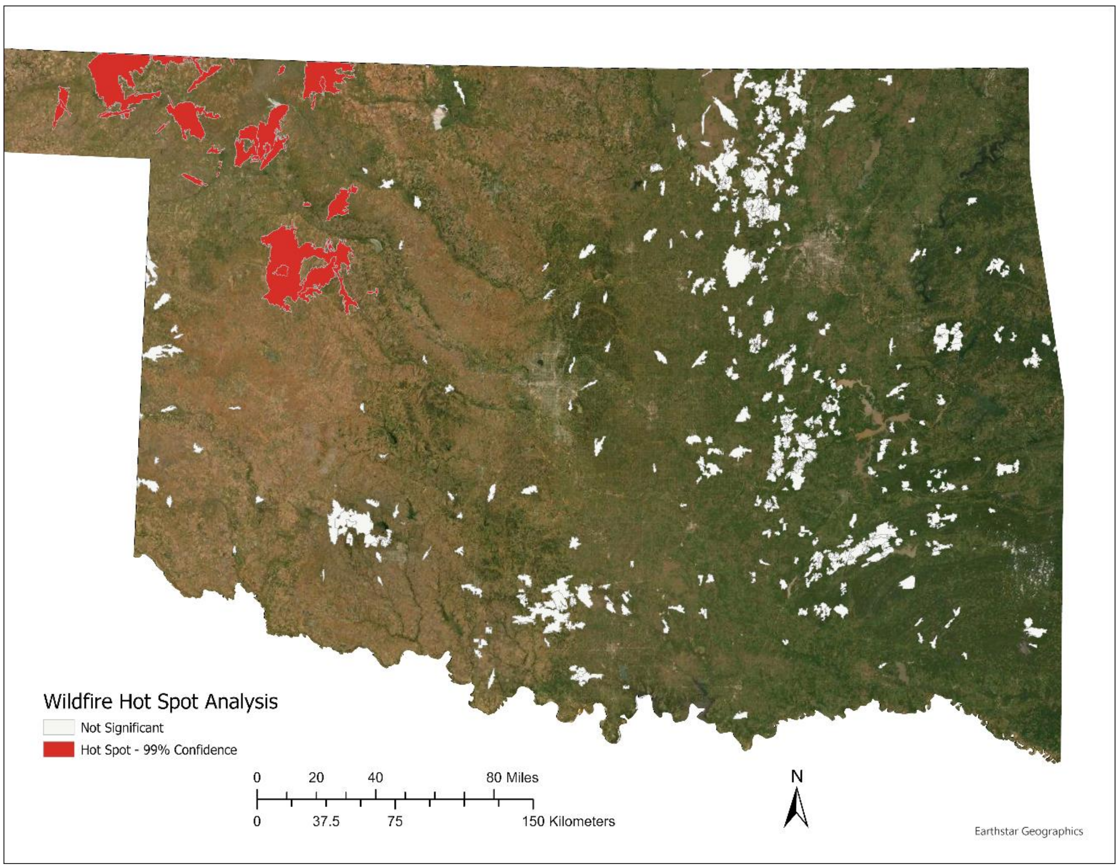


Figure 10. Wildfire Hot Spot Analysis

significant clustering of high magnitude events. This map does not feature any cold spots but does show most of the fires and locations as being insignificant. The area of the map that is of concern falls between three separate climate divisions: one, two, and four. This shows significant clustering of large wildfires at the 99% confidence level. Included in this is the Rhea fire, as well as the Anderson Creek and Starbuck fires.

Population density considers how many people reside in the area, but land cover can tell us where all the urban areas are. This gives an indication of all types of property risk rather than population risk. Figure 11 shows urban high and low intensity land cover as well as land cover including Redcedar. At the intersection of these two areas is the

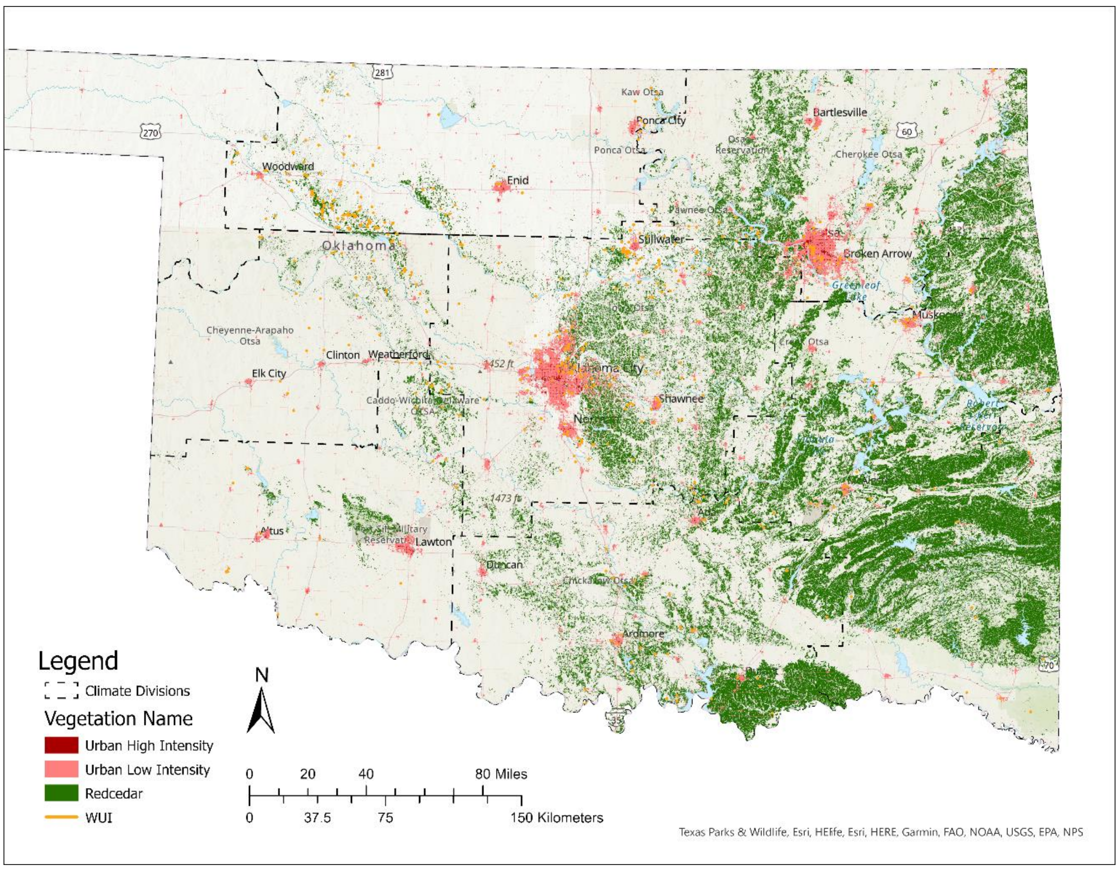


Figure 11. Land cover (OKESM)

WUI per Climate Division		
Climate division	Total length (mi)	Average length (mi)
1	231.2	115.6
2	71362.9	642.9
3	70617.8	1103.4
4	32162.8	748.0
5	153914.2	801.6
6	25574.9	730.7
7	7836.7	279.9
8	24676.7	573.9
9	12.0	8658.3

Table 2. WUI per Climate Division

wildland-urban interface. The WUI varies across the state. From visually examining Figure 11, there are spots of orange WUI that stand out. Southeast from Woodward to Watonga shows a high amount of interface. The outside edges of the large cities also show direct connections of Redcedar land cover to urban land cover.

Table 2 displays the values of WUI for each climate division. The climate division with the one of the smallest total lengths of WUI with 231 miles is climate division one (Panhandle) because of the low population density and lack of Redcedar. The top three divisions for largest value of average WUI are divisions five (Central), two (North Central), and three (Northeast). Climate division five in the central part of the state has a total of 153,914 miles of WUI. Climate division two has a high frequency of separate WUI segments at 111, while division five has more at 192 but three has sixty-four. Division two has 71,362 total miles, and division three has 70,617 total miles where

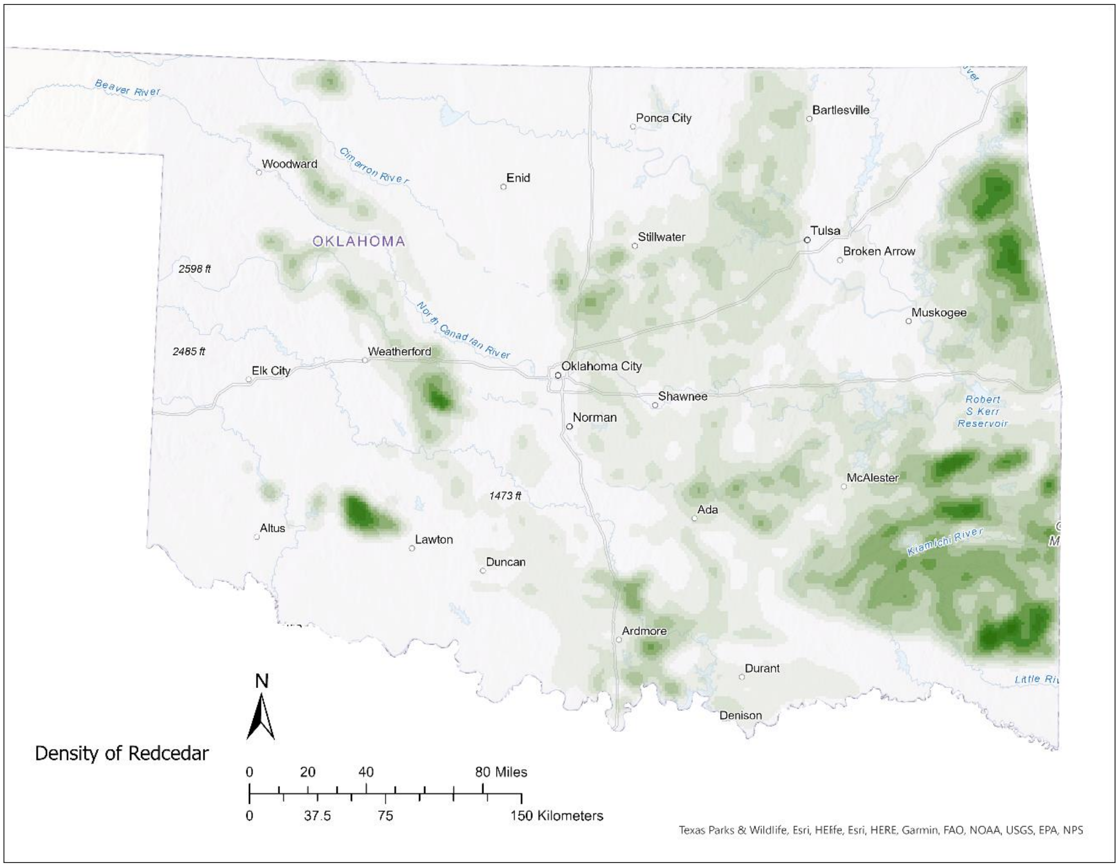


Figure 12. Redcedar density. The high densities are found in the forested regions of eastern Oklahoma, with a few notable clusters in the western half.

urban land cover and Redcedar intersect. However, because division three has fewer segments, it has the highest mean length of any division.

Figure 12 gives a better visual of the scope of Eastern Redcedar in Oklahoma. There are general regions of the state that show broad but not dense Redcedar establishment. The eastern half of the state, especially climate division nine, has a much broader cover of Redcedar with a few tiered hot spots. Redcedar cover 42% of the Southeast climate division (Table 3). The western half of the state shows very few dense areas of Eastern Redcedar land cover. Climate division four (West Central) has just 2.6% Redcedar land cover, while the panhandle has less than 1% Redcedar cover. The

Climate divisions	Area covered by cedar (sq mi)	Total area (sq mi)	Percentage
1 (Panhandle)	6.94	7980.23	0.087
2 (North Central)	255.72	8126.58	3.14
3 (Northeast)	1511.75	8516.78	17.75
4 (West Central)	160.05	6008.88	2.66
5 (Central)	1933.58	10217.29	18.92
6 (East Central)	2781.29	7138.71	38.96
7 (Southwest)	261.87	6913.29	3.78
8 (South Central)	1952.42	8535.77	22.87
9 (Southeast)	2722.67	6462.66	42.12

Table 3. Redcedar coverage per climate division

Woodward to Watonga stretch has slight cedar establishment in the area. Climate division seven (Southwest) has two dense areas in locations near Lawton and Binger, but only a total of 3.8% coverage. These are small areas of the most intense magnitude of density that stand out and are not surrounded by other areas of less density. The divisions which include Oklahoma City (division five) and Tulsa (division three) are 18.9% and 17.8% covered by Redcedar, respectively, although there are not very dense areas located in or directly adjacent to metropolitan areas.

Similar to the previous density map, Figure 13 shows a kernel density of the calculated wildland-urban interface. Two of the clusters show locations that would be expected to have a higher density of WUI. Oklahoma City shows a high density of WUI in the city and surrounding smaller cities and towns. It reaches out east into Shawnee, west to Hinton, and stretches farther south to include Moore and Norman, but the most intense part of that cluster is at the heart of Oklahoma City. Another obvious dense

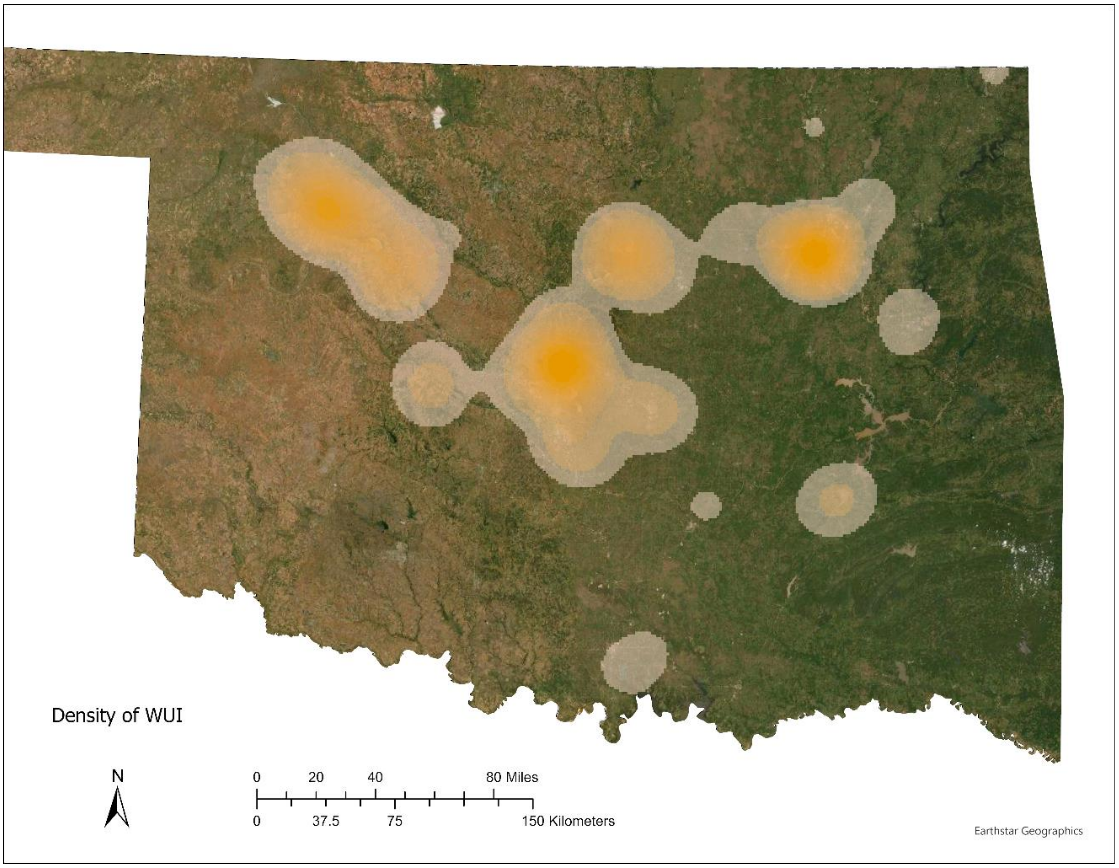


Figure 13. WUI density. The highest density is seen in urban areas of Oklahoma City and Tulsa, but several other significant clusters are present.

cluster is seen in the Tulsa area, which branches out to the more populated suburban areas in that region.

There are a few other regions that show clustering, but not near the magnitude of Oklahoma City and Tulsa. Along the Red River, Ardmore displays a small zone where wildland-urban interface is present. Muskogee in the eastern part of the state and Ada in central Oklahoma also have the same intensity of density in their respective areas, with Ada being just a small bubble in the locality. A place with a bit more intensity that was unexpected is McAlester. Closer to the municipality is a darker orange center, with a decent spread of lower level intensity in the surrounding areas.

A few areas that were highlighted in the kernel density map are unexpected, including a large swath in the north western quadrant of the state and the region around Stillwater. Stillwater has more density of WUI than some of the cities of comparable size like Ada or Ardmore. This area of density also bridges the gap between the two large clusters of Oklahoma City and Tulsa, connecting them to each other; however, the cluster near Stillwater is almost entirely contained in the same climate division as Oklahoma City. The dense region in the northwest part of the state starts near Woodward, continues north of Seiling, where the densest region can be found, and ends with Watonga in the outer southeastern bands. This spot crosses between two climate divisions, the north central and west central.

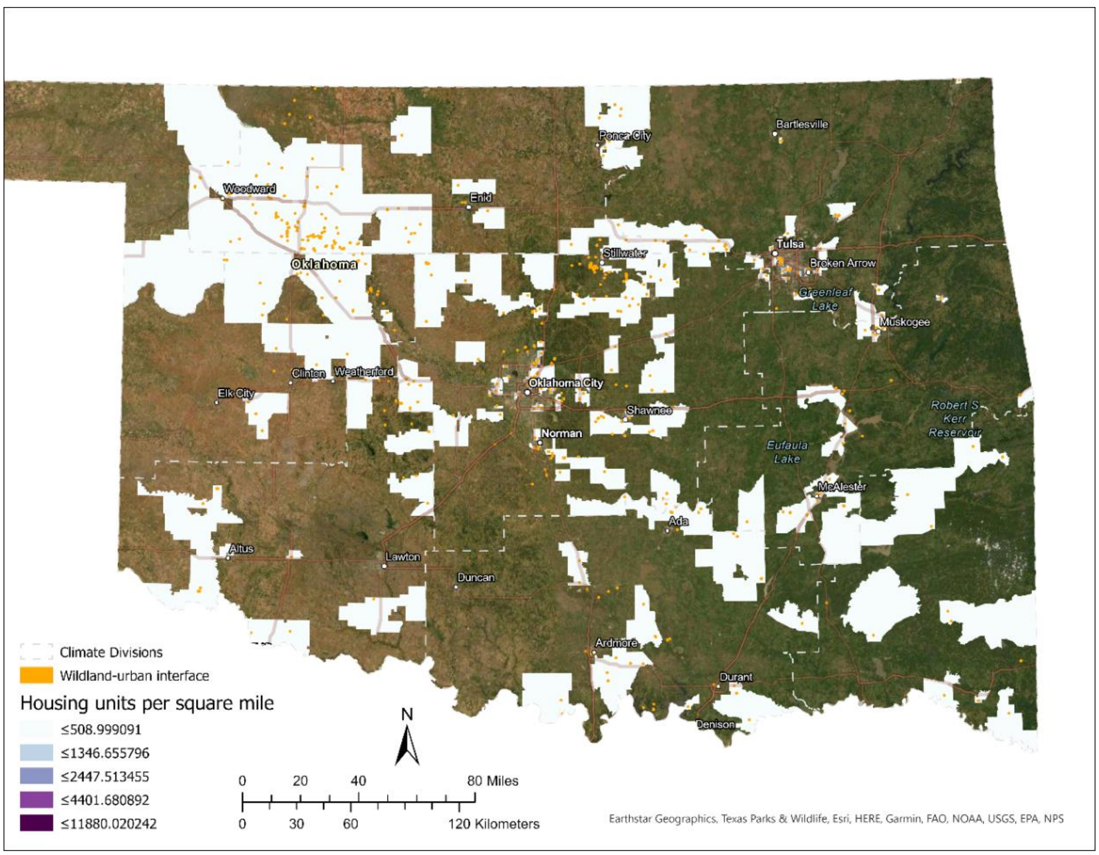


Figure 14. Housing density and WUI

Figure 14 highlights the block groups that are at risk of Redcedar wildfire by analyzing the housing density. The vast majority of the housing density falls in the group that is fewer than 508 units per square mile. Without a close look at the map, it would be hard to tell where the density is greatest. Logically, we know that Oklahoma City and Tulsa and their metro areas would have the highest densities and the map confirms this. Some areas along the fringes of the city that also stand out as having a higher housing density than others include Shawnee, Yukon, and Muskogee.

The climate divisions with highest housing densities in risk areas of Redcedar ignition are three (Northeast), five (Central), and six (East Central). Climate divisions three and five both have large metropolitan areas that account for the first and third spots in the list of housing densities, respectively. Tulsa's division has a housing density of 70 housing units per square mile of quarter mile buffers along the WUI (Table 4). The total housing units in close proximity to Redcedar is almost 43,000 units. Oklahoma City's climate division comes in third for housing density in the risk zone. There are 19 units

Housing Density per Climate Division within Quarter Mile Buffer			
Climate Division	Total housing units	Area (sq mi)	Density
1	1615	1273.5	1.3
2	12233	4244.7	2.9
3	42899	611.8	70.1
4	7236	2431.9	3.0
5	69477	3770.2	18.4
6	18259	914.8	20.0
7	6842	1770.0	3.9
8	11371	2109.0	5.4
9	9059	2097.5	4.3

Table 4. Housing density within quarter mile buffer

per square mile in the quarter mile WUI buffer zone, but there are many more units in total to worry about. With over 69,000 within these block groups, climate division five would top the list for the total housing units. Climate division six comes in second place within the quarter mile buffer with 20 housing units per square mile. This includes areas like McAlester, Muskogee, and Lake Eufaula.

The climate divisions with the lowest housing densities that are at risk of wildfire within a quarter mile are one (Panhandle), two (North Central), and four (West Central). Climate division one in the Panhandle only has 1,615 total houses at risk within a quarter mile of the WUI. The housing density is just over one unit per square mile. Divisions two and four have 12,233 and 7,236 units respectively, but both have just under 3 units per square mile at risk.

Within the half mile buffer zone, the list shifts (Table 5). Still at the top is climate division three, but division five, containing Oklahoma City, overtook division six in density. Climate division three has 105 houses per square mile at risk. Division five has 26.8 houses per square mile, and division six has 14.2 houses per square mile. The central

Housing Density per Climate Division within a Half Mile Buffer			
Climate divisions	Total housing units	Area (sq mi)	Density
1	3884.0	3217.2	1.2
2	17172.0	3736.3	4.6
3	68630.0	653.6	105.0
4	6609.0	2412.1	2.7
5	93795.0	3495.2	26.8
6	26348.0	1854.3	14.2
7	5439.0	1212.0	4.5
8	9335.0	1827.5	5.1
9	9041.0	1516.6	6.0

Table 5. Housing density per climate division within half mile buffer

division has the highest total housing units at risk with 93,795. This is much greater than division three with 66,967 total houses at risk within a half mile buffer. The panhandle still has the lowest density with just over 1 house per square mile. Division two overtook four with a density of 4.6 over 2.7.

Figure 15 shows the results of a half and quarter mile buffer being calculated around the wildland-urban interface line features over the population density of the state by block groups. The quarter mile buffer zone had varying populations at risk per climate division (Table 6). The Panhandle had the smallest magnitude of risk to population with a density of 0.7 persons per square mile and a total of 5 people within a quarter mile from

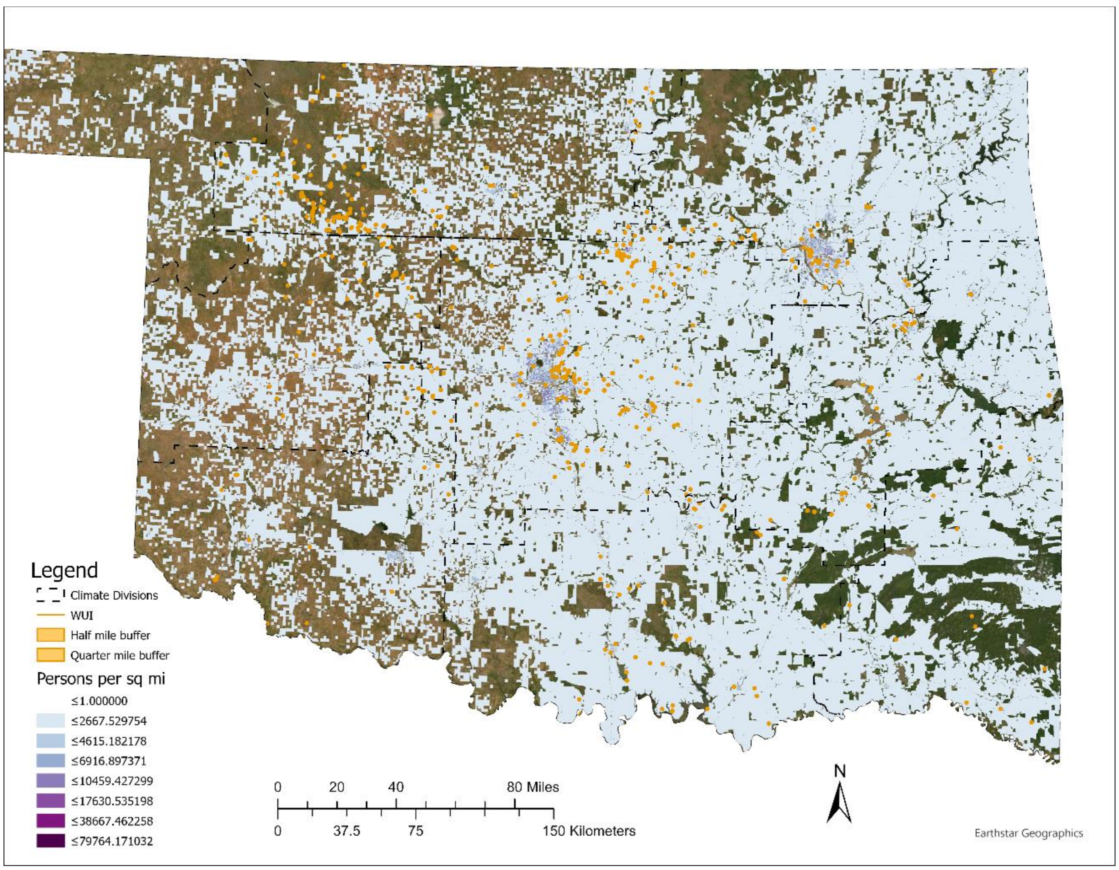


Figure 15. WUI and population density

an area with Redcedar. Climate division two in the north central part of the state has the second lowest population density within a quarter mile of WUI. Division two has over 4,100 people at risk but a density of only seven per square mile.

Climate divisions three, five, and six in the Northeast, Central, and East Central regions, respectively, took the top three spots of population per square mile within a close proximity to Redcedar and WUI. Tulsa's northeast climate division, that has no other major areas with a high frequency of WUI, has the highest population density within the quarter mile buffer at 493 persons per square mile. Oklahoma City's climate division five has a population density of 194, which is a significant difference from division three. An interesting point to consider is that climate division five has a higher total number of people at risk at almost 86,000, while climate division three only has 36,700 within a quarter mile of WUI. This puts the risk for division three's population at 3.35% and five at 5.04%.

The results of the half mile buffer agree with the quarter mile buffer (Table 7). Climate divisions one and two have the lowest population densities at 0.4 and 12.7

Population Density per Climate Division within a Quarter Mile Buffer			
Climate Divisions	Total population	Area (sq mi)	Density
1	5	7.0	0.7
2	4196	595.0	7.1
3	36704	74.4	493.2
4	2362	197.5	12.0
5	85867	442.1	194.2
6	11665	70.5	165.5
7	2431	111.2	21.9
8	7486	223.2	33.5
9	1884	67.0	28.1

Table 6. Population density at risk within quarter mile buffer

Population Density per Climate Division within a Half Mile Buffer			
Climate divisions	Total population	Area (sq mi)	Density
1 (Panhandle)	14	35.0	0.4
2 (North Central)	8804	691.4	12.7
3 (Northeast)	88650	119.0	745.3
4 (West Central)	3757	258.8	14.5
5 (Central)	164631	649.4	253.5
6 (East Central)	22691	116.8	194.3
7 (Southwest)	4115	119.2	34.5
8 (South Central)	14307	280.3	51.0
9 (Southeast)	3704	106.2	34.9

Table 7. Population density per climate division within half mile buffer

persons per square mile. The Panhandle shows a risk to only fourteen total people. The top three again were climate divisions three, five, and six. The densities of three and five are 745.3 and 253.5 persons per square mile respectively. Again, climate division five has more total population at risk with 164,631, or 9.7% of the total division population, compared to 88,650, or 8.1%. The east central climate division has an average of 194.3 persons per square mile, or 7.7% of the population at risk of wildfire.

CHAPTER IV: DISCUSSION

Wildfires can be found all over the state and the magnitude greatly varies from year to year. The Southwest climate division saw a fair number of wildfires as it should because fire is expected to be more frequent in the drier and hotter parts of the state (Scasta et al., 2016). Climate division six (East Central) saw a high frequency of fire because of the woody land cover in that part of the state, but the area burned was the lowest. This indicates that these fires are small and more manageable. Because of the wetter conditions, fuel is usually not as dry, so fire intensity is typically less. This makes fire more manageable with the resources available to efficiently respond.

Climate division two (North Central) saw a much lower frequency of fires but was the top division for area burned by wildfire. These fires were much larger magnitude, and some burned for multiple days. This is opposite of how climate division six functions, with small, short fires, but occurring more often. This area is also drier and dominated by grasslands so fires can spread more quickly. With a lower population in this climate division, there are not as many resources available, and no close fire stations to respond when fires first spark. This could also mean that there is less of a threat to people and property because there are not as many established towns with stores and homes. Climate division four in the West Central region follows suit with climate division two with the low frequency but high area burned. Again, there is not a huge population in this climate division, so large fires could be happening for the same reasons in climate division two; however, this area is warmer and drier, which could be contributing to larger magnitude fires (Weir et al., n.d.).

The first method of determining the population and property at risk was by looking at the number of housing units within a quarter and half mile buffer of the calculated WUI (Radeloff et al., 2018). It is expected to see climate divisions three and five at the top of the list. With the two highest population cities in Oklahoma within these climate divisions, it makes sense that their housing densities follow suit (Figure 16 and 17). Housing in these divisions can be found in multiple different forms. There are apartments in the downtown regions of Oklahoma City and Tulsa that house many residents in as many housing units but only cover a small area. When apartments are right next to groves of cedar, this can pose a threat to a lot of people and property. It is more likely that apartments within the city would be near park or urban green areas instead of forested areas that would cause concern for safety. It is also more likely that these areas fall within a municipality and have access to resources and fast response from a fire department (Figure 5).

The outskirts of the cities are where attention should be focused for wildfire threat. More people are building on the fringes of cities and in the suburbs (Drake and Todd, 2002). These areas are generally more dedicated to family housing than city centers. Some of the greenery could be parks in neighborhoods in the suburbs, but it is also more common to find groves of trees in close proximity to housing units on the outskirts of towns. New developments could directly back up to forests and dense vegetation. These areas are of greater concern because response times will be longer, as some of these regions could be on the edge or might not be within a municipality. It is important to put the right management and prevention practices into place before an uncontrolled fire breaks out (Bidwell et al., 2017).

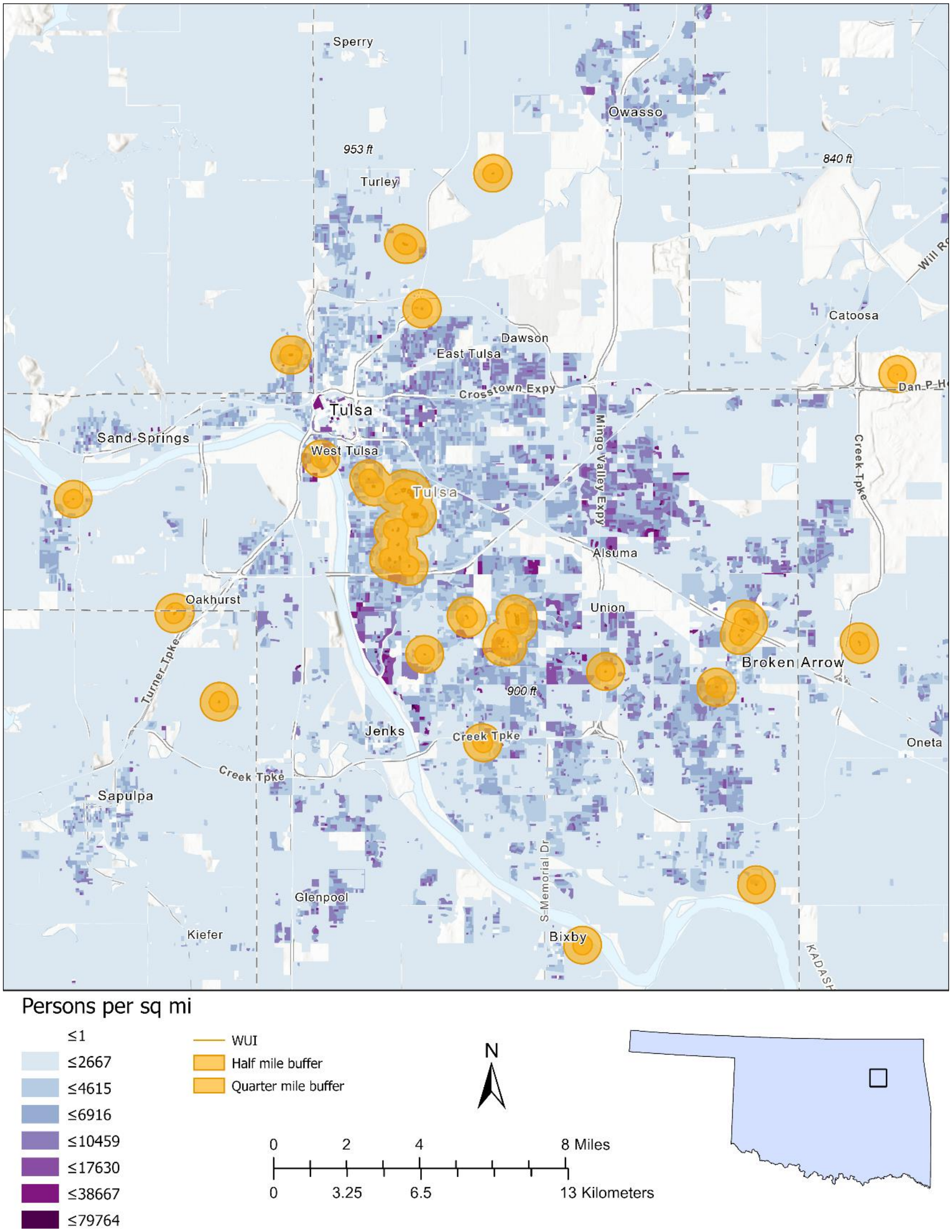


Figure 16. Population density at risk within quarter and half mile buffer zones in Tulsa

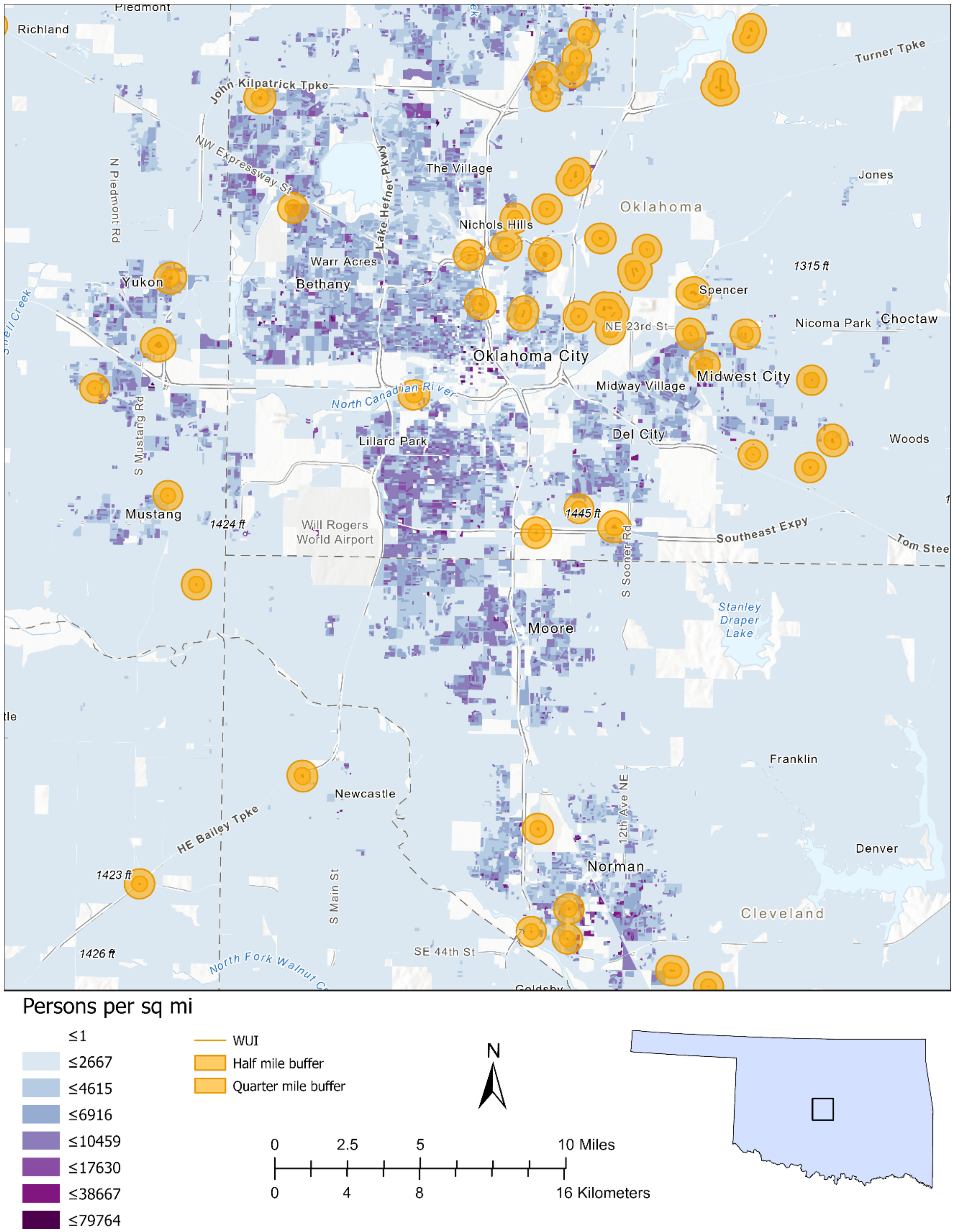


Figure 17. Population density at risk within a quarter and half mile buffer in Oklahoma City, OK

An example of this is the Marshall Fire that broke out at the end of 2021 south of Boulder, Colorado. This fire started along the wildland-urban interface in Boulder but soon took a turn for the worst. With the high wind speeds, the fire was out of control almost as quickly as it began. Oklahoma experiences many high wind events every year. Warm winds will blow through the dry landscape creating the perfect environment for a wildfire to spread. The Marshall Fire is believed to have been ignited by a resident in the area. As soon as the wind swept it away, the fire headed directly towards a city where over 1,000 homes and seven commercial buildings were destroyed (*Marshall Fire After Action Report*, 2021). With the warmer temperatures and drier conditions Oklahoma has been facing and will face in the future, our cities are not exempt from this happening to them. As the suburbs begin to expand into each other, they create the perfect link for a fire to follow.

One area that stands out in climate division five that is not directly correlated with either Oklahoma City or Tulsa is Stillwater, Oklahoma. This town only covers a small area and does not have a high population. The majority of the population is students. The large buffer region to the southwest of town is notable (Figure 18). This area is entirely housing on the outskirts of the city. There are large undeveloped regions intermixed that are covered in trees, including Redcedar. If one area sparks and starts a fire, it could easily spread into the surrounding vegetation and creep into the neighborhoods and city of Stillwater. Having a high density also adds to the risk factor since humans are usually causing the fires (Radeloff et al, 2018).

The lowest housing densities in the maximum buffer distance of a half mile fall in climate divisions four (West Central) and one (Panhandle). Just because their housing

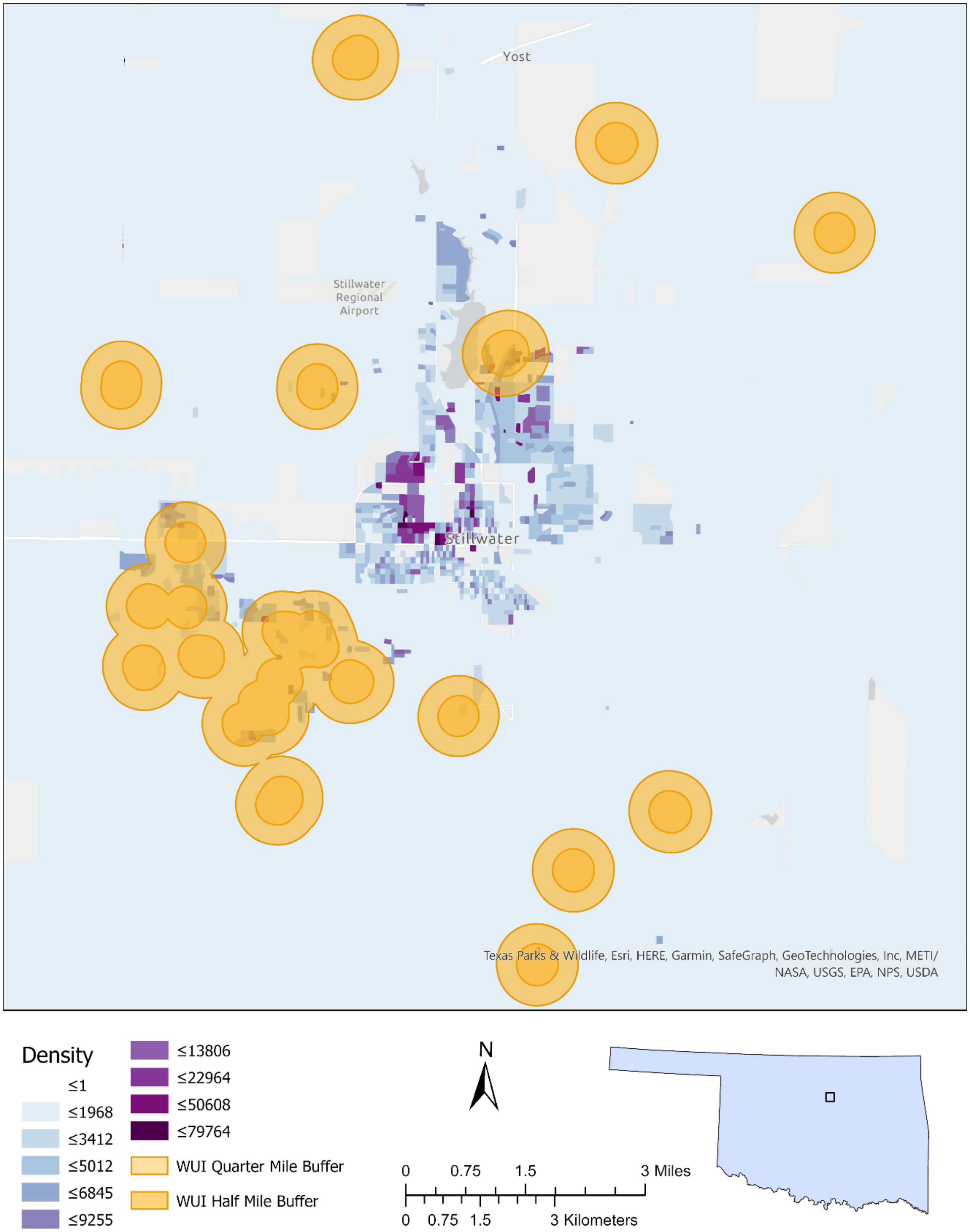


Figure 18. Population density at risk within a quarter and half mile buffer in Stillwater, OK

densities are low does not mean we can ignore them completely. While there is not as much risk to human life and personal property, wildfires could still heavily impact the area. The Rhea fire in 2018 occurred within the bounds of climate division four, which burned almost 290,000 acres. But it also burned cropland and killed livestock, putting the livelihoods of the rural residents at stake. This is something that needs to be considered when it comes to land management. While studies looking at the Great Plains or the entire United States might limit their discussions to stay strictly within the definition of WUI and only worry about direct impacts to people and property, analyzing this data on a smaller scale allows us to understand impacts on a different level. Agriculture is an important part of Oklahoma that needs to be protected and only burned when it is controlled.

Another method I used to understand the magnitude of the WUI as it poses a threat to people and property was by using population density instead of the housing density (Radeloff et al, 2005). Housing density helps understand the threat to property, but population density gives insights about the people at risk. Housing could be dense where new developments are being built, but that does not mean there is a population there yet. Another factor to consider is not every housing unit is occupied. While these units could still contribute to the spread of wildfire, lives and personal property could be spared. The same buffers along the WUI were overlaid with the population density of Oklahoma to see if there was a different result (Figure 15).

Climate divisions three and five again were at the top of the list. Just like the housing density, this makes sense as these divisions include the two largest metropolitan areas in the state. Tulsa tops the list with 745 people per square mile within a half mile of the wildland-urban interface. Oklahoma City is not far behind; however, climate division five does see a higher total population at risk than three. There could be a few reasons for this. Like with the housing density analysis, Stillwater sticks out. Because they have a large area at risk but not a lot of residents, this brings the density of the climate division down. Climate division three mostly features Tulsa, and Tulsa has a more compact region at risk, but a high density within.

Another reason for this could be that more people live in the suburbs and on rural roads in climate division five (Drake and Todd, 2002). With or without Stillwater and its added area, Oklahoma City still might have a lower population density than Tulsa. Figure 16 shows the WUI and buffer zones overlaid with the population density. It is easy to see that the WUI in climate division three is clustered into one spot, whereas climate division five has a few clusters, namely OKC and Stillwater. The closeups of each city prove that this reason for a lower population density could be true (Figures 17 and 18). Oklahoma City has buffer zones along the edges of the metro area. Edmond in the north and Norman in the south both keep some of the WUI away from the capital city. There is not much WUI within Oklahoma City, especially around the downtown area, even with the addition of urban green spaces. Most of the green spaces would likely not be decorated with cedar trees.

Tulsa on the other hand is the opposite case from Oklahoma City. The wildland-urban interface and associated regions at risk are closer to the city center. A large cluster in Tulsa is in their midtown region, but the suburbs do not reach as far as Oklahoma City's. This contributes to the higher population density since it is spread over a smaller area. While climate division three receives a good amount of precipitation annually and the environment supports Redcedar growth, city planners are not using it heavily in landscaping or park diversity. These instances of WUI stem from developing into areas with Redcedar more so than cedar encroaching in because municipalities are managing the land.

On the bottom of the list in terms of population density are climate divisions one and two. Climate division one does not even boast two people per square mile in a WUI buffer zone, but climate division two jumps up to an average of 12.7 persons per square mile. The panhandle stretches past the 100th meridian at the Oklahoma-Texas border where it is incredibly rare to find Redcedar, although it has been encroaching closer (Lawson, n.d.). Climate division two has a few towns that could cause concern. The Woodward to Watonga stretch does not have a large population, but there are groves of Redcedar dispersed throughout. This is also an area where large magnitude fires have been occurring over the past twenty years (Figure 10). Similar to climate division four in the housing density table, climate division two does not pose a huge threat to population, but it could threaten agricultural production (Table 5).

Overall, identifying people and population at risk through two methods of housing and population density returns the same result. In both cases, climate divisions three and five have the highest risk to people and personal property. The Panhandle took last place in population density and housing density. Climate division two does not have much of a population but has a decent housing density. These are all factors to consider when managing resources whether at the state or local level. Land use is another incredibly important factor because it would be detrimental to many if land used for livestock grazing and farming caught fire.

Housing and population density are not the only two methods of analysis used in this paper to understand where the threat of wildfire as a result of Redcedar ignition occurs. Studying the kernel density of the WUI segments presents interesting results. Of course, the two regions with the highest density are Oklahoma City and Tulsa. We understand these are already high risk due to the number of housing units and population within their respective regions. When looking at the density of WUI with the density of Redcedar, a cluster west of OKC along I-40 near Hinton and Niles stands out (Figure 19). This falls right along the border of climate divisions four, five, and seven. Being in a few different divisions spreads the data across different categories even though it is within the

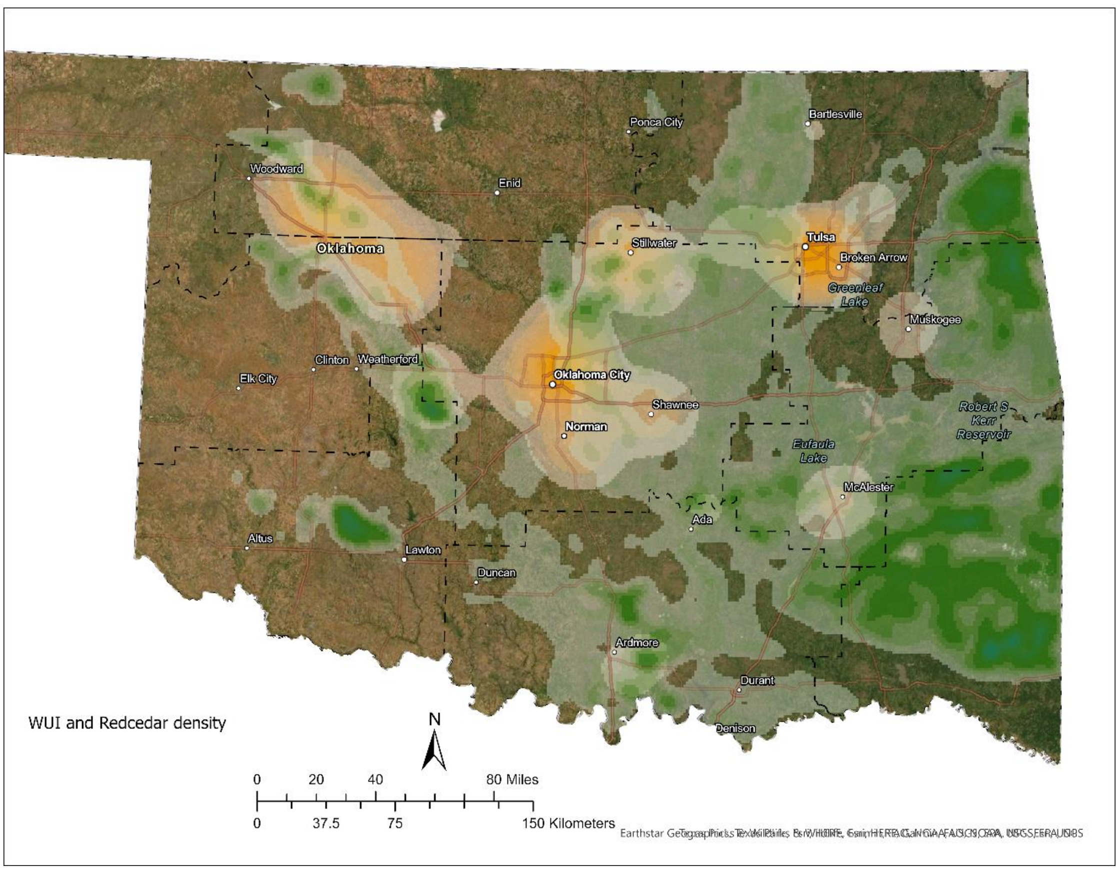


Figure 19. Redcedar and WUI densities

same cluster. The housing and population densities split across three divisions means it is not contributing a significant amount to any one area.

This WUI cluster around Hinton is starting to reach into the drier and warmer western regions of Oklahoma. It is not as likely to find Redcedar as it would be on the east side of the state. This can be seen in Figure 19 where there are dense forested regions but not a lot of overlapping WUI. Climate division seven has part of the dense cluster near Hinton, and one other region further south. The dense Redcedar region within climate division seven directly overlaps with the wildfires in the same division, although they are not considered to be of significant magnitude and clustering. This also happens to be the Wichita Mountains Wildlife Refuge. Although this land is taken care of by Fish and Wildlife Services through prescribed burns, they are still subject to fires out of their control (*Wichita Mountains Wildlife Refuge*).

Another region with a bit of overlap in WUI and Redcedar density is down I-35 just east of Ardmore. Historically, there have not been many fires down here and there are no significant hot spots within the last twenty years. Located in the Crosstimbers, this area is likely victim to encroachment of Redcedar (Drake and Todd, 2002). However, climate division eight did not show up as extremes in any of the tables. Ardmore may just be a spot to watch.

In the northwest portion of the state, there is a large, high-density region that extends across the borders of climate divisions two and four. Climate division five had the largest sum of WUI segments, but the next division was two. Climate divisions three and four followed after that. The west and north central divisions did not appear high up on any lists for population or housing density, yet they still have a high magnitude of

WUI. The WUI density lines up with a swath of Redcedar in the same area. Since it is so far west, where Redcedar are not expected to thrive, they are likely encroaching here. Without correct management, this will only continue and put more homes and people at risk while expanding the wildland-urban interface. Figure 20 visualizes the density of WUI with the hot spot analysis of wildfires that have previously occurred. This same area in the northwest shows a high density with a wildfire hot spot, meaning not only is the risk there, but it has happened before.

With recent climate trends only expected to continue and worsen, Oklahomans need to be active in managing their land and keeping their property safe from wildfire (Scasta et al., 2016). Because mechanical removal is so tedious and expensive, managing

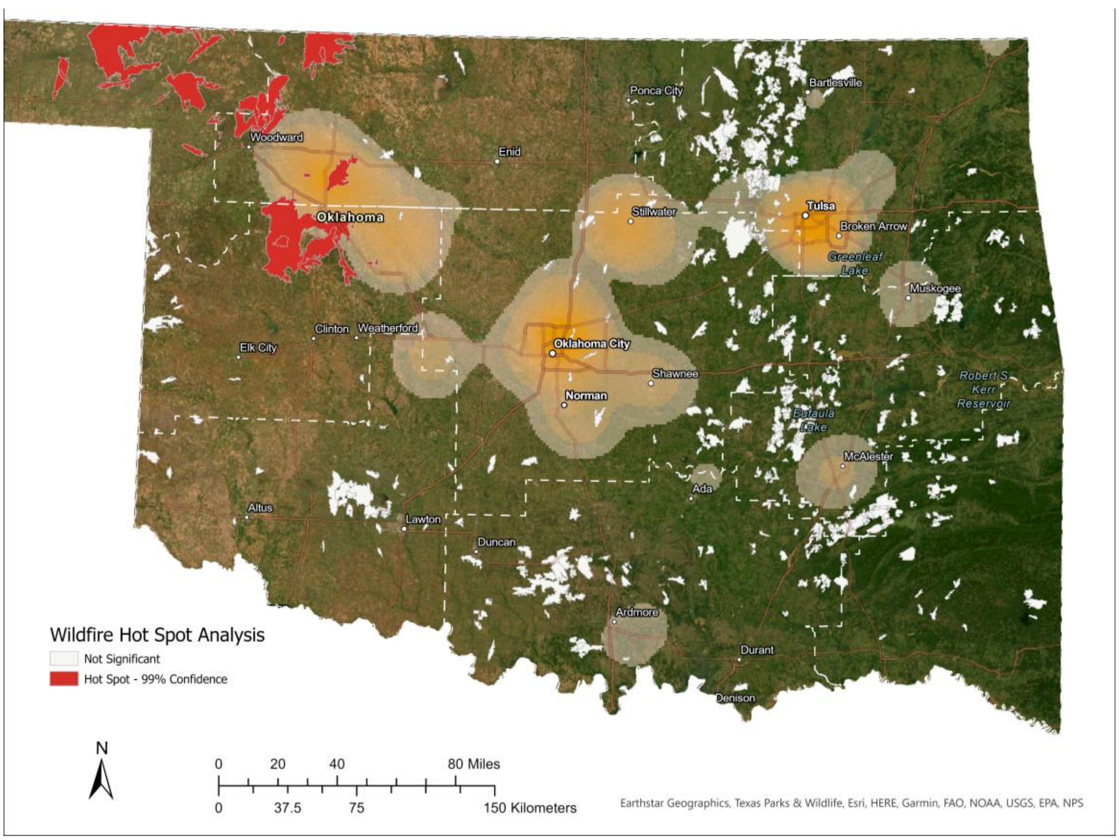


Figure 20. WUI density and wildfire hot spot analysis

land through prescribed burns is encouraged. After five or six years, Redcedar become resistant to fires, so it is important to keep up with management to kill seeds and seedlings before they mature. (Scasta et al., 2016; Twidwell et al., 2021). Being an absentee landowner makes that process difficult because seedlings often go undetected until it is too late to effectively burn them. Some landowners adapt to the situation by joining Prescribed Burn Associations to share resources and help each other. This also keeps liabilities to a minimum, which is what drives most away from controlled burning (Weir et al., 2020).

It is important to note that what has gotten us to this level of risk were the suppression measures taken place post-European settlement (Donovan et al., 2020; Twidwell et al., 2021; Donovan et al., 2017). Homeowners can mitigate some of the risk by making their home less susceptible to fire. This includes things like keeping trees a safe distance away from the home or creating a barrier around at-risk property. It can also go as far as home design and structure (Calkin et al., 2013).

4.1 Limitations

Some limitations to this research relate to the land cover classification used. While the Oklahoma Ecological Systems Map (OKESM) provides incredibly detailed land cover data, the urban land cover category only has low and high values. While the NLCD provides, low, medium, high, and open development categories, it is at 30m rather than 10m. Because of this, the less categorized but higher resolution layer was chosen. The urban categories in the OKESM consider roads as urban cover. Ideally, this information would not be included in the analysis for urban cover. Due to a lack of a consistent removal method for each climate division, roads were left in as urban land cover and could be included as some areas of WUI that might not have a threat to other manmade structures.

4.2 Relevance

This study can be used by many people in different roles. Local officials can use this document as an education resource for landowners that live within risk areas. It can also be used to educate the absentee landowners that might let their land grow naturally without much intervention to prevent woody encroachment of Redcedar. It is important that residents of communities near the WUI understand the risk and how they can help mitigate potential wildfire and spread. State and local officials may also reference this when determining how to allocate resources on a high fire danger day. Firefighters and even the National Guard can now visualize the areas at highest risk of wildfire from a hazardous fuel and better understand how to fight and manage the fire.

4.3 Conclusion

With climate trends continuing to worsen, large magnitude events are bound to occur. Wildfire frequency has already increased across the country and is expected to continue to do so. The wildland-urban interface will keep expanding, putting more people and property at risk every year (Radeloff et al., 2005; Radeloff et al, 2018). I determined that magnitude of WUI in each climate division to find that climate divisions three and five had the most people and property at risk, but divisions two and four had an unusually long length of WUI. Land managers and landowners need to practice active prevention and not suppression. The Hinton-Niles, Woodward-Watonga, and Oklahoma City and Tulsa metropolitan areas need to be particularly kept up with as these areas are where the largest risk lies for the state of Oklahoma.

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